CERTIFICATE OF VERIFICATION

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[List of Attached Documents]

[Document Name] SCOPE OF CLAIM FOR PATENT 1

[Document Name] SPECIFICATION 1

[Document Name] DRAWINGS 1

[Document Name] ABSTRACT 1

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[Document Name] SCOPE OF CLAIM FOR PATENT

[Claim 1]

An imaging lens comprising, in order from an object side: an aperture diaphragm; and three lenses which are

a first lens having a positive optical power,

a second lens having a negative optical power, and

a third lens having a positive optical power, wherein

the first lens is a bi-aspherical lens whose image side is convex,

the second lens is a bi-aspherical meniscus lens whose object side is concave and

the third lens is a bi-aspherical meniscus lens whose object side is convex, and wherein

following conditional expressions (1) to (4) are satisfied:

$$1.5 < |fd/f2d| < 2.3 \quad (1)$$

$$0.5 < |fd/f3d| < 1.1 \quad (2)$$

$$-2.2 < (r_{21}+r_{22})/(r_{21}-r_{22}) < -1.3 \quad (3)$$

$$2.1 < (r_{31}+r_{32})/(r_{31}-r_{32}) < -1.7 \quad (4)$$

wherein,

fd is a composite focal length of an entire lens system to d-line (mm),

f2d is a focal length of the second lens to the d-line (mm),

f3d is a focal length of the third lens to the d-line (mm),

r_{21} is a radius of curvature of an object side surface of the second lens (mm),

r_{22} is a radius of curvature of an image side surface of the second lens (mm),

r_{31} is a radius of curvature of an object side surface of the third lens (mm), and

r_{32} is a radius of curvature of an image side surface of the third lens (mm).

[Claim 2]

The imaging lens according to claim 1, wherein following conditional expressions (5) and (6) are satisfied:

$$60 < 2 \cdot \omega d < 70 \quad (5)$$

$$1.2 < T/fd < 1.7 \quad (6)$$

wherein,

ωd is a half view angle of the entire lens system to the d-line (unit: in degrees), and

T is an entire length between an object side surface of the first lens and the image side surface of the third lens (mm).

[Claim 3]

The imaging lens according to claim 1 or 2, wherein following conditional expressions (7) and (8) are satisfied:

$$1.4 < |fd/f1d| < 2.0 \quad (7)$$

$$0.3 < (r_{11}+r_{12})/(r_{11}-r_{12}) < 0.7 \quad (8)$$

wherein,

f1d is a focal length of the first lens to the d-line (mm),

r_{11} is a radius of curvature of the object side surface of the first lens (mm), and

r_{12} is a radius of curvature of an image side surface of the first lens (mm).

[Claim 4]

The imaging lens according to any of claims 1 to 3, wherein the second lens and the third lens have, in effective diameters, at least one point taking a value of zero for a first-order differential as to H in a following expression indicating an aspherical surface,

$$Z = \frac{(1/CR)\cdot H^2}{1+\sqrt{1-(1+K)\cdot(1/CR)^2\cdot H^2}} + \sum_{n=4}^{16} An \cdot H^n$$

wherein,

in a cylindrical coordinate system including a Z axis referring to an axis extending toward an image plane side along an optical axis direction, and an H axis referring to an axis vertically extending along a direction away from the optical axis,

CR is a paraxial radius of curvature (mm),

K is a conic coefficient, and

An is an n-th order aspherical coefficient.

[Claim 5]

The imaging lens according to any of claims 1 to 4, wherein at least the second lens and the third lens are formed from a synthetic resin material, and satisfy following conditional expressions (9) and (10):

$$25 < V2d < 35 \qquad (9)$$

$$50 < V3d < 60 \qquad (10)$$

wherein,

V2d is an Abbe number of the second lens, and

V3d is an Abbe number of the third lens.

[Claim 6]

The imaging lens according to any of claims 1 to 5, wherein the first lens satisfies a following conditional expression (11):

$$50 < V1d < 65 \qquad (11)$$

wherein,

V1d is an Abbe number of the first lens.

[Document Name] SPECIFICATION

[Title of the Invention] IMAGING LENS AND OPTICAL DEVICE

[Technical Field]

[0001]

The present invention relates to, in particular, an imaging lens suitable for a compact imaging unit using a solid-state image sensor such as a CCD, and an optical device provided with this imaging lens, such as a digital still camera or a compact camera used in a personal digital assistance.

[Background Art]

[0002]

Recently, as a digital still camera (hereinafter, referred to as a DSC) or the like has rapidly gained popularity, imaging lenses with high optical performance compatible with a large number of pixels equal to or more than five million pixels have been commercialized for use in an image input device recording a digital image. In addition, many mobile telephones or PDA terminals provided with a compact camera have been commercialized, and accepted in the marketplace. Among them, compact imaging units and imaging lenses compatible with a large number of pixels (two million to four million pixels) equivalent to that of a DSC are particularly gaining attention for use in, for example, compact cameras provided in mobile terminals or the like, in particular.

[0003]

Conventional downsized imaging units and imaging lenses can

be largely divided into two groups.

[0004]

One is imaging lenses used mainly in mobile telephones for which downsizing and cost reduction are sought, PC (personal computer) cameras, PDAs, or the like, as disclosed in Patent Document 1, for example. These are highly attractive in their sizes and costs and thereby commercialized in a large number, but not compatible with a large number of pixels, and, in many cases, they are only compatible with about one hundred thousand to three hundred fifty thousand pixels. A compact image sensor having an image quality of more than one million pixels is proposed, as disclosed in Patent Document 2, for example. However, the number of lenses therein is as many as four or more, and a less expensive, compact type is sought for portability.

[0005]

The other is in a field applied in endoscopes, surveillance cameras, or the like. The lenses achieve high optical performance and downsizing of some extent. However, the number of lenses therein is as many as six to nine to ensure the required performance, and portability and cost thereof do not allow a common use.

[Patent Document 1] Japanese Laid-Open Patent Publication No. 2003-195158

[Patent Document 2] Japanese Laid-Open Patent Publication No. 2003-149547

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0006]

In the above imaging unit and the imaging lens, in order to achieve a favorable optical performance while adopting an inexpensive configuration and trying to downsize its entire lens system, the lens shape or the like need to be appropriately configured while keeping the number of lenses to a minimum.

[0007]

Generally, in order to downsize, a refractive power of lenses is increased. However, when the refractive power of the lenses is increased, aberration occurred in each of the lenses becomes large, thereby causing a problem that favorable aberration compensation in the entire optical system is difficult.

[0008]

The object of the present invention is to provide, by employing an imaging lens configured with three, as the minimum number, lenses, and adopting an appropriate configuration for each of the lenses, the imaging lens and an optical device for which an entire lens system is downsized and a high optical performance is obtained.

[Solution to the Problems]

[0009]

In order to solve the above problem, a first invention of the present invention provides an imaging lens comprising, in order from an object side:

an aperture diaphragm; and

three lenses which are

a first lens having a positive optical power,

a second lens having a negative optical power, and

a third lens having a positive optical power, wherein

the first lens is a bi-aspherical lens whose image side is convex,

the second lens is a bi-aspherical meniscus lens whose object side is concave and

the third lens is a bi-aspherical meniscus lens whose object side is convex, and wherein

following conditional expressions (1) to (4) are satisfied.

[0010]

The conditional expressions are:

$$1.5 < |fd/f2d| < 2.3 \quad (1)$$

$$0.5 < |fd/f3d| < 1.1 \quad (2)$$

$$-2.2 < (r_{21}+r_{22})/(r_{21}-r_{22}) < -1.3 \quad (3)$$

$$-2.1 < (r_{31}+r_{32})/(r_{31}-r_{32}) < -1.7 \quad (4)$$

here,

fd is a composite focal length of an entire lens system to d-line (mm),

f2d is a focal length of the second lens to the d-line (mm),

f3d is a focal length of the third lens to the d-line (mm),

r_{21} is a radius of curvature of an object side surface of

the second lens (mm),

r_{22} is a radius of curvature of an image side surface of the second lens (mm),

r_{31} is a radius of curvature of an object side surface of the third lens (mm), and

r_{32} is a radius of curvature of an image side surface of the third lens (mm).

A second invention of the present invention provides the imaging lens according to the first invention, satisfying following conditional expressions (5) and (6).

[0011]

The conditional expressions are:

$$60 < 2 \cdot \omega d < 70 \qquad (5)$$

$$1.2 < T/fd < 1.7 \qquad (6)$$

wherein,

ωd is a half view angle of the entire lens system to the d-line (unit: in degrees), and

T is an entire length between an object side surface of the first lens and the image side surface of the third lens (mm).

A third invention of the present invention provides the imaging lens according to the first or second invention, satisfying following conditional expressions (7) and (8).

[0012]

The conditional expressions are:

$$1.4 < |fd/f1d| < 2.0 \qquad (7)$$

$$0.3 < (r_{11}+r_{12})/(r_{11}-r_{12}) < 0.7 \quad (8)$$

wherein,

f1d is a focal length of the first lens to the d-line (mm),

r_{11} is a radius of curvature of the object side surface of the first lens (mm), and

r_{12} is a radius of curvature of an image side surface of the first lens (mm).

A fourth invention of the present invention provides the imaging lens according to any of the first to third inventions, wherein the second lens and the third lens have, in effective diameters, at least one point taking a value of zero for a first-order differential as to H in a following expression Z indicating an aspherical surface.

[0013]

[Numerical formula 1]

$$Z = \frac{(1/CR)\cdot H^2}{1+\sqrt{1-(1+K)\cdot(1/CR)^2\cdot H^2}} + \sum_{n=4}^{16} An \cdot H^n$$

[0014]

In a cylindrical coordinate system including a Z axis referring to an axis extending toward an image plane side along an optical axis direction, and an H axis referring to an axis vertically extending along a direction away from the optical axis,

CR is a paraxial radius of curvature (mm),

K is a conic coefficient, and

An is an n-th order aspherical coefficient.

A fifth invention of the present invention provides the imaging lens according to any of the first to fourth inventions, wherein at least the second lens and the third lens are formed from a synthetic resin material, and satisfy following conditional expressions (9) and (10).

[0015]

The conditional expressions are:

$$25 < V2d < 35 \qquad (9)$$

$$50 < V3d < 60 \qquad (10)$$

wherein,

V2d is an Abbe number of the second lens, and

V3d is an Abbe number of the third lens.

A sixth invention of the present invention provides the imaging lens according to any of the first to fifth inventions, wherein the first lens satisfies a following conditional expression (11).

[0016]

The conditional expression is:

$$50 < V1d < 65 \qquad (11)$$

wherein,

V1d is an Abbe number of the first lens.

[Effect of the Invention]

[0017]

According to the present invention, it is possible to obtain an imaging lens and an optical device having an entire lens system

downsized, being excellent in portability, and being compatible with a large number of pixels by which a favorable image quality is provided.

[Best Mode for Carrying Out the Invention]

[0018]

Hereinafter, an embodiment of the present invention is described.

[0019]

FIGs. 1, 3, 5, 7, 9, 11, 13, 15, and 17 are schematic configuration diagrams illustrating imaging lenses according to Examples 1, 2, 3, 4, 5, 6, 7, 8, and 9 of the present invention, respectively.

[0020]

In each of the diagrams, in order from an object side, 100 denotes an aperture diaphragm, 101 denotes a first lens (hereinafter, refers to as an "L1"), 102 denotes a second lens (hereinafter, refers to as an "L2"), 103 denotes a third lens (hereinafter, refers to as an "L3"), 104 denotes an optical low-pass filter (hereinafter, refers to as an "OLPF"), 105 denotes an image plane, and 106 denotes a solid-state image sensor such as a CCD.

[0021]

The first lens L1, the second lens L2, and the third lens L3 are all lenses having aspherical surfaces on both faces. The shapes of these aspherical surfaces are represented by the following expression.

[0022]

[Numerical formula 2]

$$Z = \frac{(1/CR)\cdot H^2}{1+\sqrt{1-(1+K)\cdot(1/CR)^2\cdot H^2}} + \sum_{n=4}^{16} An \cdot H^n$$

[0023]

In a cylindrical coordinate system including a Z axis referring to an axis extending toward an image plane side along an optical axis direction, and an H axis referring to an axis vertically extending along a direction away from the optical axis, CR is a paraxial radius of curvature (mm), K is a conic coefficient, and An is an n-th order aspherical coefficient.

[0024]

The first lens L1 is a lens, formed by a glass material or from a synthetic resin material, of aspherical surfaces on both faces, and having a positive refractive power. The second lens L2 is a lens, formed from the synthetic resin material, of aspherical surfaces on both faces, and having a negative refractive power. The third lens L3 is a lens, formed from the synthetic resin material, of aspherical surfaces on both faces, and having a positive refractive power.

[0025]

In order to obtain a compact body and a favorable image quality in the present invention, refractive power of the second lens L2 and the third lens L3 need to be designed with appropriate values, and bending shape thereof also need to be designed with appropriate

values. For this reason, it is preferable that the following conditional expressions are satisfied.

[0026]

The conditional expressions are:

$$1.5 < |fd/f2d| < 2.3 \quad (1)$$

$$0.5 < |fd/f3d| < 1.1 \quad (2)$$

$$-2.2 < (r_{21}+r_{22})/(r_{21}-r_{22}) < -1.3 \quad (3)$$

$$-2.1 < (r_{31}+r_{32})/(r_{31}-r_{32}) < -1.7 \quad (4)$$

Here,

fd is a composite focal length of the entire lens system to d-line (mm),

f2d is a focal length of the second lens L2 to the d-line (mm),

f3d is a focal length of the third lens L3 to the d-line (mm),

r_{21} is a radius of curvature of an object side surface of the second lens L2 (mm),

r_{22} is a radius of curvature of an image side surface of the second lens L2 (mm),

r_{31} is a radius of curvature of an object side surface of the third lens L3 (mm), and

r_{32} is a radius of curvature of an image side surface of the third lens L3 (mm).

[0027]

The above conditional expression (1) indicates the

refractive power of the second lens L2 with respect to refractive power of the entire lens system. When the lower limit of the expression is exceeded, chromatic aberration is insufficiently compensated, causing difficulties in obtaining a favorable image quality. Also, when the upper limit thereof is exceeded, the amount of aberration occurrence in a single lens corresponding to the second lens L2 becomes excessively large, causing difficulties in obtaining a favorable image quality in the entire lens system.

[0028]

The conditional expression (2) indicates the refractive power of the third lens L3 with respect to the refractive power of the entire lens system. When the lower limit of the expression is exceeded, a position of principal points for the entire lens system becomes excessively close to the image side, causing difficulties in downsizing and in obtaining a favorable image quality. Also, when the upper limit thereof is exceeded, the amount of aberration occurrence in a single lens corresponding to the third lens L3 becomes excessively large, causing difficulties in obtaining a favorable image quality in the entire lens system, and simultaneously, the tilt angle of a surface in the neighborhood of an effective diameter of the image side surface r_{32} of the third lens L3 becomes excessively large, causing difficulties in manufacturing thereof.

[0029]

The conditional expression (3) represents a shape factor

indicating a bending shape of the second lens L2. When the lower limit of the expression is exceeded, spherical aberration due to the object side surface r_{21} thereof occurs in a large amount, and, when the upper limit thereof is exceeded, astigmatism due to the image side surface r_{22} of the second lens L2 occurs in a large amount, causing difficulties in obtaining a favorable quality in either case.

[0030]

The conditional expression (4) represents a shape factor indicating a bending shape of the third lens L3. When the lower limit of the expression is exceeded, astigmatism occurs in a large amount, and, when the upper limit thereof is exceeded, spherical aberration due to the image side surface r_{32} of the third lens L3 occurs in a large amount, causing difficulties in obtaining a favorable quality in either case.

[0031]

More preferably, in consideration of lens manufacturing, it is preferable that the tilt angle of a surface θ_{32} in the neighborhood of the effective diameter of the image side surface r_{32} of the third lens L3 satisfies the following conditional expression (13).

[0032]

The conditional expression is:

$\theta_{32} < 67$ (unit: in degrees) (13)

When the above θ_{32} exceeds the upper limit of the conditional

expression (13), it is advantageous for distortion compensation and astigmatism compensation, however, not only precision for the shape of the aspherical surfaces is reduced, but also precision for shape management is reduced, thereby causing difficulties in stably producing lenses.

[0033]

As for the entire lens system, in order to achieve downsizing and a favorable image quality, an angle of view ($2\cdot\omega d$) and an entire length of the lens system are required to be set to appropriate values. When the angle of view is set wide, a focal length is shortened, and therefore, it is advantageous for downsizing. However, aberration compensation has to be favorably performed at wide angle of view, and particularly, compensation for astigmatism or distortion is difficult.

[0034]

On the other hand, when the angle of view is set narrow, the focal length needs to be set long, and therefore, it is disadvantageous when requiring downsizing, but astigmatism or distortion is easily compensated.

[0035]

Consequently, in the present invention, it is preferable that the following conditional expressions are satisfied to achieve downsizing in the entire lens system and a favorable image quality.

[0036]

The conditional expressions are:

$$60 < 2 \cdot \omega d < 70 \quad (5)$$

$$1.2 < T/fd < 1.7 \quad (6)$$

Here,

ωd is a half view angle of the entire lens system to the d-line (unit: in degrees), and

T is an entire length between the object side surface r_{11} of the first lens L1 and the image plane 106 (mm).

[0037]

In the above conditional expression (5), a usual standard angle of view is set (about 35 mm using a 135 film camera).

[0038]

In a case of downsizing the entire length of the entire lens system, the most favorable image quality is obtained by satisfying the above condition. When the ωd exceeds the upper limit of the above condition, the angle of view becomes narrow, and the focal length becomes long thereby lengthening the entire length. Therefore, downsizing cannot be achieved. When the ωd exceeds the lower limit thereof, the angle of view becomes excessively wide. Therefore, astigmatism and distortion cannot be compensated.

[0039]

The conditional expression (6) is an expression indicating the ratio between the entire length of the above lens system and the focal length of the entire lens system. In order to achieve downsizing and a favorable image quality, this conditional

expression needs to be satisfied. When the lower limit of the condition is exceeded, aberration on each of the lens surfaces occurs in a large amount, and therefore, a favorable image quality as a whole cannot be obtained. When the upper limit thereof is exceeded, downsizing cannot be achieved, thereby resulting in a less attractive imaging lens.

[0040]

In the present invention, in order to obtain a compact body and a favorable image quality, the refractive power of the first lens L1 needs to be designed with an appropriate value, and the bending shape also needs to be designed with an appropriate value.

[0041]

Therefore, it is preferable that the following conditional expressions are satisfied.

[0042]

The conditional expressions are:

$$1.4 < |fd/f1d| < 2.0 \qquad (7)$$

$$0.3 < (r_{11}+r_{12})/(r_{11}-r_{12}) < 0.7 \qquad (8)$$

Here,

f1d is a focal length of the first lens L1 to the d-line (mm),

r_{11} is a radius of curvature of the object side surface of the first lens L1 (mm), and

r_{12} is a radius of curvature of the image side surface of the first lens L1 (mm).

The above conditional expression (7) indicates the refractive power of the first lens L1 with respect to the refractive power of the entire lens system. When the lower limit of the expression is exceeded, a position of paraxial exit pupil for the entire lens system becomes excessively close to an image side, whereby an incident angle of an off-axial principal ray onto the image plane 105 cannot be reduced. When the upper limit thereof is exceeded, the amount of aberration occurrence in a single lens corresponding to the first lens L1 becomes excessively large, and simultaneously, the tilt angle of a surface in the neighborhood of an effective diameter of the image side surface r_{12} of the first lens L1 becomes excessively large, thereby causing difficulties in manufacturing thereof. In consideration of the lens manufacturing, more preferably, it is preferable that the tilt angle of a surface θ_{12} in the neighborhood of the effective diameter of the image side surface r_{12} of the first lens L1 satisfies the following conditional expression.

[0043]

Also, the above conditional expression (8) represents a shape factor indicating a bending shape of the first lens L1. When the lower limit of the expression (8) is exceeded, spherical aberration and astigmatism at a high position of an image height occur in a large amount, and, when the upper limit thereof is exceeded, coma aberration occurs in a large amount, thereby causing difficulties in obtaining a favorable quality in either case.

[0044]

The conditional expression is:

$\theta_{12} < 56$ (unit: in degrees) (14)

In the conditional expression (14), when the θ_{12} exceeds the upper limit thereof, it is advantageous for distortion compensation and astigmatism compensation, however, not only precision for the shape of the aspherical surfaces is reduced, but also precision for shape management is reduced, thereby causing difficulties in stably producing lenses.

[0045]

Also, in the second lens L2 and the third lens L3, it is preferable to have, in their effective diameters, at least one point taking a value of zero for a first-order differential of Z with respect to H (dZ/dH), where Z is depicted in the following expression indicating an aspherical surface.

[0046]

[Numerical formula 3]

$$Z = \frac{(1/CR)\cdot H^2}{1+\sqrt{1-(1+K)\cdot(1/CR)^2\cdot H^2}} + \sum_{n=4}^{16} An \cdot H^n$$

[0047]

In a cylindrical coordinate system including: a Z axis referring to an axis extending toward an image plane side along an optical axis direction; and an H axis referring to an axis vertically extending along a direction away from the optical axis, CR is a paraxial radius of curvature (mm), K is a conic coefficient,

and An is an n-th order aspherical coefficient.

[0048]

In the second lens L2 and the third lens L3, when at least one point taking a value of zero for the dZ/dH is provided in the effective diameters, distortion is favorably compensated, and the incident angle of the off-axial principal ray onto the image plane 105 is advantageously reduced. Also, through reducing the incident angle of the off-axial principal ray onto the image plane 105, shading causing an illuminance reduction is effectively reduced.

[0049]

Also, in the second lens L2 and the third lens L3, in order for chromatic aberration and a curvature of field, as a whole, to be compensated in a favorably well balanced manner, it is preferable that each of Abbe numbers satisfies the following conditional expressions.

[0050]

The conditional expressions are:

$$25 < V2d < 35 \qquad (9)$$

$$50 < V3d < 60 \qquad (10)$$

The Abbe number refers to a value calculated from refractive indices to d-line (587.56nm), F-line (486.13nm), and C-line (656.27nm), and is represented by the following expression.

[0051]

[Numerical formula 4]

$$Vd = \frac{(Nd - 1)}{(Nf - Nc)}$$

[0052]

Nd, Nf, Nc are refractive indices to d-line, F-line, and C-line, respectively.

[0053]

The above conditional expressions (9) and (10) respectively designate the Abbe numbers of a material for the second lens L2 and the third lens L3. In the conditional expression (9), when V2d exceeds the lower limit thereof, chromatic aberration is favorably compensated, but a Petzval sum for the entire lens system becomes excessively large whereby the curvature of field becomes large, and, when V2d exceeds the upper limit thereof, the chromatic aberration is insufficiently compensated, and simultaneously, the refractive power of each lens is required to be more increased, whereby the amount of aberration occurring in a single lens becomes excessively large, causing difficulties in obtaining a favorable image quality in either case.

[0054]

In the above conditional expression (10), when V3d exceeds the lower limit thereof, chromatic aberration of magnification, in particular, occurs in a large amount, and, when V3d exceeds the upper limit thereof, the chromatic aberration of magnification is excessively compensated, and simultaneously, the Petzval sum

for the entire lens system becomes large whereby the curvature of field becomes large, causing difficulties in obtaining a favorable image quality in either case.

[0055]

Also, it is preferable that the first lens L1 satisfies the following conditional expression in order for the chromatic aberration as a whole to be favorably compensated.

[0056]

The conditional expression is:

$$50 < V1d < 65 \qquad (11)$$

The above conditional expression (11) designates an Abbe number of a material for the first lens L1. When the lower limit of the conditional expression (11) is exceeded, axial chromatic aberration is insufficiently compensated, and, when the upper limit thereof is exceeded, chromatic aberration can be favorably compensated, but the Petzval sum becomes large whereby the curvature of field becomes large, causing difficulties in obtaining a favorable image quality in either case.

[0057]

The aperture diaphragm 100 is positioned on a side closest to an object, and therefore, the incident angle of the off-axial principal ray onto the image plane 105 can be reduced, and shading causing an illuminance reduction is effectively reduced.

[0058]

Also, in order to achieve downsizing for the lenses, it is

preferable that the incident angle is maintained in a reasonable range, and therefore, it is desired to set an appropriate value to the incident angle of the off-axial principal ray.

[0059]

Therefore, more preferably, it is preferable that the maximum incident angle of the off-axial principal ray onto the image plane 105 (θmax) satisfies the following conditional expression.

[0060]

The conditional expression is:

$$10 < \theta max < 25 \text{ (unit: in degrees)} \qquad (12)$$

In the above conditional expression (12), when the θmax exceeds the lower limit thereof, the entire lens system cannot be downsized, and, when the θmax exceeds the upper limit thereof, shading becomes large, thereby substantially reducing ambient illuminance.

[0061]

The OLPF 104 is constructed with a material having birefringent characteristics, such as a crystal. The solid-state image sensor 106 such as a CCD takes an object image, formed by the imaging lens, as a two dimensional sampling image having a low numerical aperture. Therefore, high frequencies equal to or more than half of sampling frequency become false signals. In order to eliminate such high frequency components of an image in advance, it is preferable that the OLPF 104 is positioned between the third lens L3 and the image plane 105.

[0062]

Also, more preferably, because the solid-state image sensor 106 is generally highly sensitive to light in the infrared region, in order to have natural color reproduction, the OLPF 104 is preferably provided with an IR cut function for filtering out the light in the infrared region, by providing an IR absorbing material or coating.

[0063]

Hereinafter, concrete numeral data corresponding to Examples 1 to 9 are shown as Numerical examples 1 to 9.

[0064]

[Table 1]

(Numerical example 1)

Surface number	Radius of curvature Rd	Distance d	Refractive index nd	Abbe number νd
1	INF	0.35		
2	4.89911	1.152	1.60602	57.5
3	-2.08542	0.6618		
4	-0.95475	0.987	1.58387	30.9
5	-4.51679	0.3675		
6	2.23064	2.1594	1.53116	56.0
7	6.60981	0.3		
8	INF	0.43	1.51633	64.1
9	INF	0		

Aspherical coefficient

Surface number	K	A4	A6	A8	A10	A12	A14	A16
2	2.58408E+01	-6.84156E-02	-6.21333E-02	1.07211E-02	-9.07655E-02	1.35421E-02	1.17743E-01	-1.68189E-01
3	1.33811E+00	-2.70276E-02	-1.35115E-02	-9.19301E-03	1.44867E-02	-1.70906E-03	-6.42628E-03	2.30094E-03
4	-8.70576E-01	1.31794E-01	-4.89178E-02	-4.57772E-02	1.71945E-01	-1.90392E-01	9.95169E-02	-2.01315E-02
5	3.44373E+00	1.75856E-02	1.53343E-02	1.02894E-02	-6.70791E-03	-2.17982E-04	9.16302E-04	-1.74721E-04
6	-8.44035E+00	-6.94865E-03	2.98410E-04	2.78163E-04	-6.31408E-05	4.89103E-06	-9.36535E-08	-2.19446E-08
7	-3.42779E+00	-1.79099E-02	2.36410E-03	-5.19999E-04	5.68945E-05	-2.98338E-06	1.42863E-07	-1.05161E-08

[0065]

[Table 2]

(Numerical example 2)

Surface number	Radius of curvature Rd	Distance d	Refractive index nd	Abbe number ν d
1	INF	0.35		
2	4.89911	1.152	1.60602	57.5
3	-2.08542	0.6618		
4	-0.95813	1.0269	1.58387	30.9
5	-4.5325	0.3363		
6	2.25852	2.1588	1.53116	56.0
7	6.6461	0.3		
8	INF	0.43	1.51633	64.1
9	INF	0		

Aspherical coefficient

Surface number	K	A4	A6	A8	A10	A12	A14	A16
2	2.58408E+01	-6.84156E-02	-6.21334E-02	1.07210E-02	-9.07655E-02	1.35422E-02	1.17743E-01	-1.68189E-01
3	1.33811E+00	-2.70276E-02	-1.35115E-02	-9.19300E-03	1.44867E-02	-1.70906E-03	-6.42628E-03	2.30094E-03
4	-8.70591E-01	1.31839E-01	-4.89233E-02	-4.59445E-02	1.71757E-01	-1.90481E-01	9.95151E-02	-2.00899E-02
5	3.47582E+00	1.77139E-02	1.52622E-02	1.02421E-02	-6.72504E-03	-2.21724E-04	9.16884E-04	-1.73322E-04
6	-8.50891E+00	-6.72094E-03	3.35327E-04	2.67567E-04	-6.40441E-05	4.91179E-06	-7.78488E-08	-1.88608E-08
7	-2.05058E+00	-1.78476E-02	2.25532E-03	-5.22183E-04	5.74739E-05	-2.94368E-06	1.43928E-07	-1.05904E-08

[0066]

[Table 3]

(Numerical example 3)

Surface number	Radius of curvature Rd	Distance d	Refractive index nd	Abbe number νd
1	INF	0.35		
2	4.89911	1.152	1.60602	57.5
3	−2.08542	0.6618		
4	−0.9582	1.0272	1.58387	30.9
5	−4.53286	0.336		
6	2.24956	2.2162	1.53116	56.0
7	6.57816	0.3		
8	INF	0.43	1.51633	64.1
9	INF	0		

Aspherical coefficient

Surface number	K	A4	A6	A8	A10	A12	A14	A16
2	2.58408E+01	−6.84156E−02	−6.21334E−02	1.07210E−02	−9.07655E−02	1.35422E−02	1.17743E−01	−1.68189E−01
3	1.33811E+00	−2.70276E−02	−1.35115E−02	−9.19300E−03	1.44867E−02	−1.70906E−03	−6.42628E−03	2.30094E−03
4	−8.70481E−01	1.31820E−01	−4.89328E−02	−4.59531E−02	1.71754E−01	−1.90477E−01	9.95204E−02	−2.00904E−02
5	3.47671E+00	1.77170E−02	1.52602E−02	1.02408E−02	−6.72558E−03	−2.21879E−04	9.16894E−04	−1.73257E−04
6	−8.37097E+00	−6.17947E−03	5.63553E−04	2.28399E−04	−6.18810E−05	5.00436E−06	−9.86419E−08	−1.25937E−08
7	−2.93906E+00	−1.65471E−02	2.09079E−03	−4.91484E−04	5.77343E−05	−3.23446E−06	1.25237E−07	−6.90898E−09

[0067]

[Table 4]

(Numerical example 4)

Surface number	Radius of curvature Rd	Distance d	Refractive index nd	Abbe number νd
1	INF	0.35		
2	5.13176	1.1858	1.60602	57.5
3	−2.0626	0.6495		
4	−0.95563	0.9102	1.58387	30.9
5	−4.58256	0.3929		
6	2.19872	2.0549	1.53116	56.0
7	7.86594	0.3		
8	INF	0.43	1.51633	64.1
9	INF	0		

Aspherical coefficient

Surface number	K	A4	A6	A8	A10	A12	A14	A16
2	2.58465E+01	−6.53643E−02	−5.70615E−02	5.12728E−03	−1.00546E−01	1.01476E−02	1.27524E−01	−1.43226E−01
3	1.35899E+00	−2.84020E−02	−1.37565E−02	−8.67808E−03	1.46609E−02	−2.02273E−03	−6.68782E−03	2.46902E−03
4	−8.59214E−01	1.29496E−01	−4.83813E−02	−4.65824E−02	1.70338E−01	−1.90674E−01	1.00189E−01	−2.02053E−02
5	3.54447E+00	1.75573E−02	1.51694E−02	1.01856E−02	−6.75128E−03	−2.34773E−04	9.13041E−04	−1.71567E−04
6	−7.61925E+00	−9.00511E−03	6.82672E−04	1.87463E−04	−6.52365E−05	4.93797E−06	−7.56999E−08	−7.47629E−09
7	2.31319E+00	−1.59024E−02	1.73506E−03	−5.04314E−04	5.83937E−05	−3.22142E−06	1.22810E−07	−7.29160E−09

[0068]

[Table 5]

(Numerical example 5)

Surface number	Radius of curvature Rd	Distance d	Refractive index nd	Abbe number νd
1	INF	0.35		
2	4.89864	1.1632	1.60602	57.5
3	-2.10663	0.6586		
4	-0.95927	0.9151	1.58387	30.9
5	-4.74767	0.4043		
6	2.22455	2.1242	1.53116	56.0
7	8.24416	0.3		
8	INF	0.43	1.51633	64.1
9	INF	0		

Aspherical coefficient

Surface number	K	A4	A6	A8	A10	A12	A14	A16
2	2.56578E+01	-6.51569E-02	-6.19700E-02	3.22834E-03	-9.17943E-02	3.03517E-02	1.30271E-01	-1.88547E-01
3	1.34723E+00	-2.89314E-02	-1.32113E-02	-8.12905E-03	1.45408E-02	-2.42841E-03	-6.94103E-03	2.93831E-03
4	-8.63825E-01	1.30469E-01	-4.72208E-02	-4.58781E-02	1.71000E-01	-1.90131E-01	1.00571E-01	-2.04289E-02
5	3.43006E+00	1.71864E-02	1.52386E-02	1.02819E-02	-6.77267E-03	-2.27277E-04	9.20742E-04	-1.70615E-04
6	-7.86820E+00	-9.62610E-03	7.39677E-04	2.03989E-04	-6.48984E-05	4.97891E-06	-7.77507E-08	-8.26887E-09
7	1.62582E+00	-1.60072E-02	1.82955E-03	-4.98787E-04	5.84831E-05	-3.22768E-06	1.19122E-07	-7.79576E-09

[0069]

[Table 6]

(Numerical example 6)

Surface number	Radius of curvature Rd	Distance d	Refractive index nd	Abbe number νd
1	INF	0.35		
2	9.33932	1.2068	1.60602	57.5
3	-2.06529	0.8427		
4	-1.06161	0.8985	1.58387	30.9
5	-4.94499	0.3928		
6	2.23042	1.96	1.53116	56.0
7	8.2278	0.3		
8	INF	0.43	1.51633	64.1
9	INF	0		

Aspherical coefficient

Surface number	K	A4	A6	A8	A10	A12	A14	A16
3	1.50629E+01	-4.61001E-02	-5.76962E-02	1.68626E-01	-2.23054E-01	-2.54078E-01	6.27470E-01	-2.68138E-01
4	1.27418E+00	-7.67609E-03	1.00519E-02	-9.23062E-03	5.86144E-03	2.74694E-03	-1.31625E-02	8.23648E-03
5	-8.37673E-01	1.66725E-01	-3.99077E-02	4.14765E-02	-3.81093E-02	-6.22095E-03	1.99685E-02	-5.64656E-03
6	-7.95426E+00	1.24542E-02	3.23980E-02	-7.33465E-03	-1.48070E-03	3.26087E-05	3.01644E-04	-5.01424E-05
7	-8.78752E+00	1.74804E-03	-1.97116E-03	7.53928E-04	-1.05983E-04	8.11665E-07	1.18909E-06	-8.80260E-08
8	-9.66135E-01	-1.64663E-02	2.24248E-03	-4.81394E-04	5.82643E-05	-2.55354E-06	1.06431E-09	-2.05121E-09

[0070]

[Table 7]

(Numerical example 7)

Surface number	Radius of curvature Rd	Distance d	Refractive index nd	Abbe number νd
1	INF	0.35		
2	5.96632	1.4353	1.60602	57.5
3	−2.15509	0.7346		
4	−0.95508	0.8608	1.58387	30.9
5	−3.5575	0.3905		
6	2.31838	2.1115	1.53116	56.0
7	7.30243	0.3		
8	INF	0.48	1.51633	64.1
9	INF	0		

Aspherical coefficient

Surface number	K	A4	A6	A8	A10	A12	A14	A16
3	3.31383E+01	−5.25450E−02	−1.68418E−02	−8.09347E−03	3.71994E−03	−3.41435E−02	6.98813E−02	−5.21320E−02
4	9.46842E−01	−5.67226E−03	1.19113E−02	−5.62526E−03	4.54769E−03	−2.72360E−03	1.05920E−03	4.55049E−05
5	−9.39180E−01	1.83795E−01	−1.97922E−02	−7.25830E−03	−2.59880E−03	2.95957E−03	1.60233E−05	−1.45957E−04
6	−9.68356E+00	1.30891E−02	3.37407E−02	−8.19573E−03	−8.59144E−04	2.08738E−04	1.01812E−04	−1.77164E−05
7	−8.09959E+00	−4.08196E−03	3.01222E−04	2.16750E−04	−5.48952E−05	5.57781E−06	−2.08037E−07	−4.00912E−09
8	−2.77554E+00	−1.58978E−02	2.11087E−03	−4.66261E−04	5.64875E−05	−3.18946E−06	1.03448E−07	−4.25283E−09

[0071]

[Table 8]

(Numerical example 8)

Surface number	Radius of curvature Rd	Distance d	Refractive index nd	Abbe number νd
1	INF	0.3246		
2	6.4703	1.2495	1.60602	57.5
3	-1.8236	0.733		
4	-0.8238	0.938	1.58387	30.9
5	-2.9321	0.2201		
6	2.00602	1.75	1.52996	55.8
7	5.7801	0.3		
8	INF	0.48	1.51633	64.1
9	INF	0		

Aspherical coefficient

Surface number	K	A4	A6	A8	A10	A12	A14	A16
3	-7.52521E+00	-4.75316E-02	-3.26435E-02	1.72094E-02	4.94040E-02	-3.12602E-01	4.60163E-01	-2.16665E-01
4	9.54561E-01	-1.00819E-02	3.15306E-02	-2.32362E-02	1.26067E-02	4.52437E-03	-7.33530E-03	3.64479E-03
5	-7.86540E-01	2.79708E-01	-2.30800E-02	-1.18459E-02	-8.33045E-03	1.61864E-02	-3.84045E-03	-4.82111E-04
6	-3.03037E+00	3.19352E-04	7.34520E-02	-2.36939E-02	-1.67352E-03	1.37139E-03	3.73315E-04	-1.49276E-04
7	-9.80269E+00	-6.08300E-03	4.47725E-03	-1.81717E-03	1.58301E-04	1.08348E-04	-3.05909E-05	2.14842E-06
8	-1.09384E+01	-3.18431E-02	1.24005E-02	-4.40912E-03	7.60818E-04	-3.81712E-05	-3.95205E-06	3.48905E-07

[0072]

[Table 9]

(Numerical example 9)

Surface number	Radius of curvature Rd	Distance d	Refractive index nd	Abbe number νd
1	INF	0		
2	3.9653	0.8889	1.52996	57.5
3	−1.8248	0.7145		
4	−0.6965	0.5212	1.58387	30.9
5	−1.9538	0.3		
6	1.4842	1.1411	1.52996	55.8
7	5.4462	0.3		
8	INF	0.3	1.51633	64.1
9	INF	0		

Aspherical coefficient

Surface number	K	A4	A6	A8	A10	A12	A14	A16
3	7.30796E+00	−1.11507E−01	−1.16775E−02	−1.80257E−01	6.21600E−01	−3.93257E+00	1.01325E+01	8.81289E+00
4	5.64495E−01	−8.03762E−02	5.99553E−02	−2.23847E−01	2.28892E−01	2.52605E−01	−6.47077E−01	3.04581E−01
5	−1.42200E+00	2.41434E−01	−7.28519E−02	1.83016E−01	−3.94518E−01	5.41646E−01	−4.29104E−01	1.26357E−01
6	−2.86305E+00	2.42264E−02	1.88105E−01	−1.16615E−01	3.62356E−02	−3.56405E−03	−2.37857E−03	−2.03370E−04
7	−7.23765E+00	−4.26307E−03	−3.48968E−03	3.96766E−03	−8.79389E−04	−7.60369E−04	4.00258E−04	−5.48302E−05
8	−2.11172E+00	−3.52522E−02	6.27474E−03	9.74512E−04	−1.43137E−03	2.77429E−04	4.75851E−06	−4.54756E−06

[0073]

FIGs. 2, 4, 6, 8, 10, 12, 14, 16, and 18 are aberration diagrams corresponding to Numerical examples 1 to 9.

[0074]

In these aberration diagrams, (a) is a graph showing spherical aberration (SA), (b) is a graph showing astigmatism (AST), and (c) is a graph showing distortion (DIS).

[0075]

Table 10 shows values for the above numerical examples and numerical values for the conditional expressions.

[0076]

[Table 10]

Table for numerical values of conditional expressions

		Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9
	fd	5.013	5.026	4.999	4.995	5.038	5.261	5.174	4.500	3.780
	f1d	2.574	2.574	2.574	2.589	2.593	2.907	2.799	2.489	2.491
	f2d	−2.309	−2.327	−2.328	−2.279	−2.260	−2.531	−2.547	−2.347	−2.188
	f3d	5.413	5.502	5.465	5.104	5.110	5.174	5.576	4.995	3.500
Conditional expression (1)	fd／f2d	2.170	2.160	2.148	2.192	2.229	2.079	2.032	1.917	1.728
Conditional expression (2)	fd／f3d	0.926	0.914	0.915	0.979	0.986	1.017	0.928	0.901	1.080
Conditional expression (3)	(r21＋r22)／(r21−r22)	−1.536	−1.536	−1.536	−1.527	−1.506	−1.547	−1.734	−1.781	−2.108
Conditional expression (4)	(r31＋r32)／(r31−r32)	−2.019	−2.030	−2.039	−1.776	−1.739	−1.744	−1.930	−2.063	−1.749
Conditional expression (5)	2・ωd	66.926	67.538	67.230	67.222	66.840	65.190	66.054	63.506	62.084
Conditional expression (6)	T／fd	1.409	1.410	1.418	1.415	1.406	1.410	1.440	1.474	1.399
Conditional expression (7)	fd／f1d	1.947	1.953	1.942	1.930	1.943	1.810	1.848	1.808	1.518
Conditional expression (8)	(r11＋r12)／(r11−r12)	0.403	0.403	0.403	0.427	0.399	0.638	0.469	0.560	0.370
Conditional expression (9)	V2d	30.900	30.900	30.900	30.900	30.900	30.900	30.900	30.900	30.900
Conditional expression (10)	V3d	55.800	55.800	55.800	55.800	55.800	55.800	55.800	55.800	55.800
	T	7.063	7.086	7.088	7.067	7.084	7.419	7.450	6.632	5.288

[0077]

With reference to FIG. 19, there is described an embodiment for an optical device provided with imaging lenses according to the above embodiments and numerical examples.

[0078]

In FIG. 19, 191 denotes a body of the optical device, such as a digital camera, provided with the imaging lens of the present invention, 192 denotes the imaging lens, 193 denotes an optical finder separately incorporated in the body of the optical device, 194 denotes a strobe light, and 195 denotes a release button.

[0079]

By providing the imaging lens of the present invention with an optical device such as a digital camera, as above, a compact optical device with high optical performance can be achieved.

[Industrial Applicability]

[0080]

The present invention is effective in providing an imaging lens having a small number of lenses and with high optical performance, and an optical device such as a digital camera, which is compact and of high optical performance, by having the imaging lens therein.

[Brief Description of the Drawings]

[0081]

[FIG. 1] A schematic configuration diagram of an imaging lens according to Example 1 of the present invention

[FIG. 2] An aberration diagram of the imaging lens according to Example 1 of the present invention

[FIG. 3] A schematic configuration diagram of an imaging lens according to Example 2 of the present invention

[FIG. 4] An aberration diagram of the imaging lens according to Example 2 of the present invention

[FIG. 5] A schematic configuration diagram of an imaging lens according to Example 3 of the present invention

[FIG. 6] An aberration diagram of the imaging lens according to Example 3 of the present invention

[FIG. 7] A schematic configuration diagram of an imaging lens according to Example 4 of the present invention

[FIG. 8] An aberration diagram of the imaging lens according to Example 4 of the present invention

[FIG. 9] A schematic configuration diagram of an imaging lens according to Example 5 of the present invention

[FIG. 10] An aberration diagram of the imaging lens according to Example 5 of the present invention

[FIG. 11] A schematic configuration diagram of an imaging lens according to Example 6 of the present invention

[FIG. 12] An aberration diagram of the imaging lens according to Example 6 of the present invention

[FIG. 13] A schematic configuration diagram of an imaging lens according to Example 7 of the present invention

[FIG. 14] An aberration diagram of the imaging lens

according to Example 7 of the present invention

[FIG. 15] A schematic configuration diagram of an imaging lens according to Example 8 of the present invention

[FIG. 16] An aberration diagram of the imaging lens according to Example 8 of the present invention

[FIG. 17] A schematic configuration diagram of an imaging lens according to Example 9 of the present invention

[FIG. 18] An aberration diagram of the imaging lens according to Example 9 of the present invention

[FIG. 19] A schematic diagrammatic perspective view of an optical device showing an embodiment of the present invention

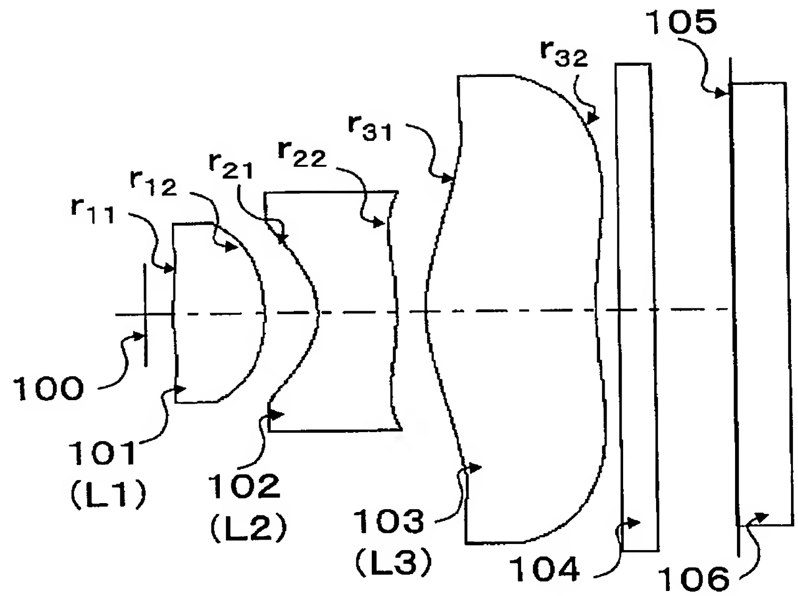
[Description of the Reference Characters]

[0082]

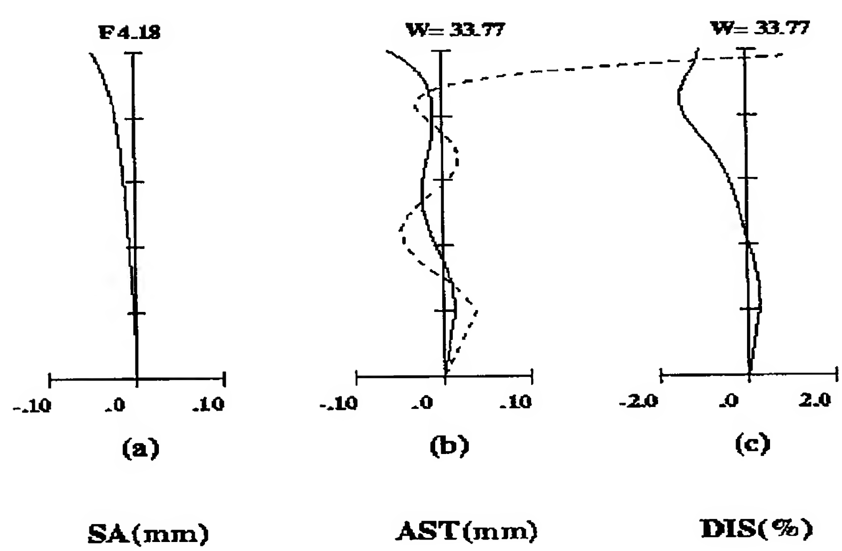
100	Aperture diaphragm
101(L1)	First lens
102(L2)	Second lens
103(L3)	Third lens
104	Optical low-pass filter
105	Image plane
106	Solid-state image sensor
191	Body of optical device

[Document Name] DRAWINGS

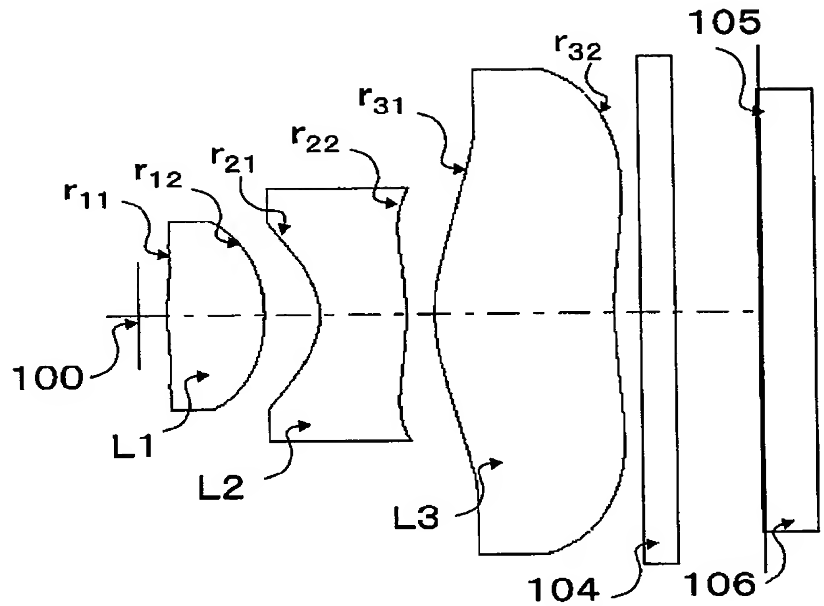
[FIG.1]



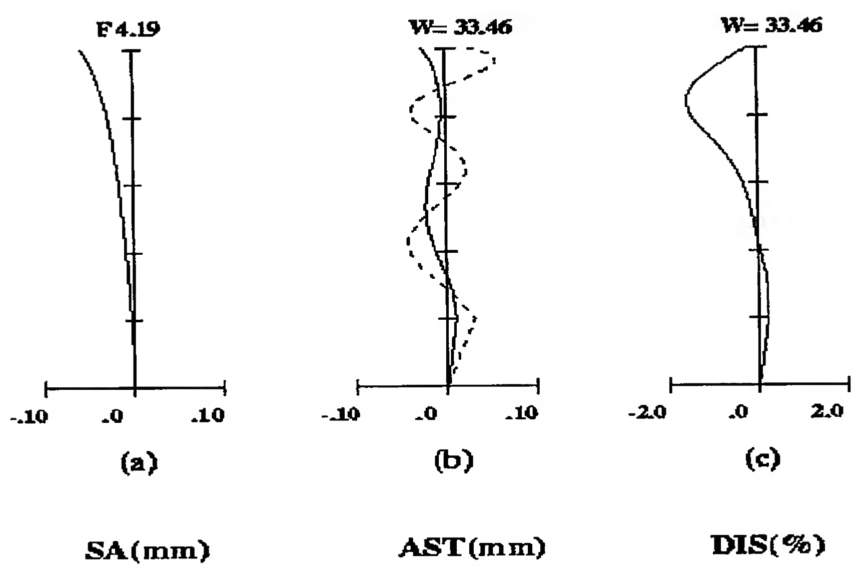
[FIG.2]



[FIG.3]


105
r32
r31
r22
r21
r12
r11
100
L1
L2
L3
104
106

[FIG.4]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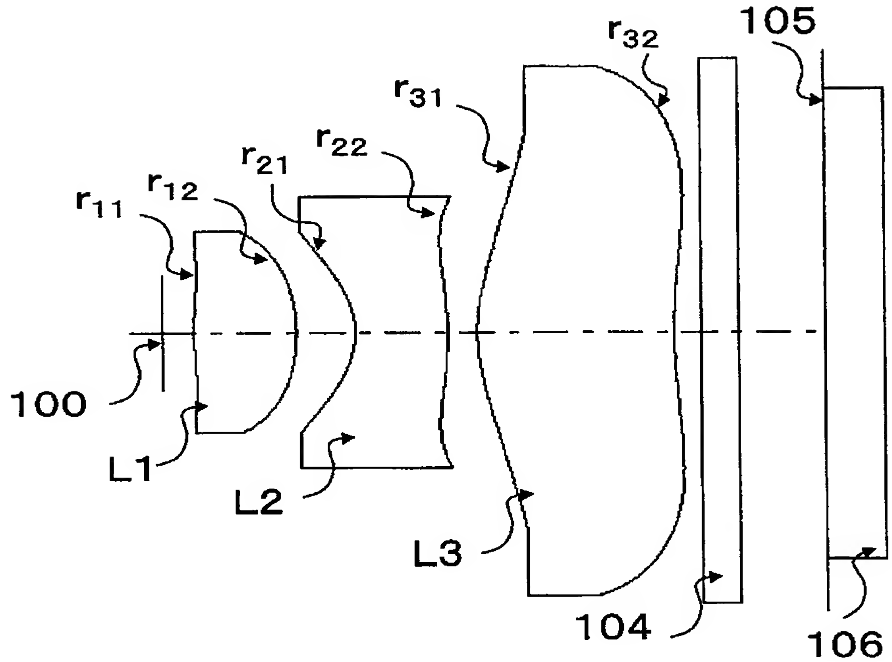
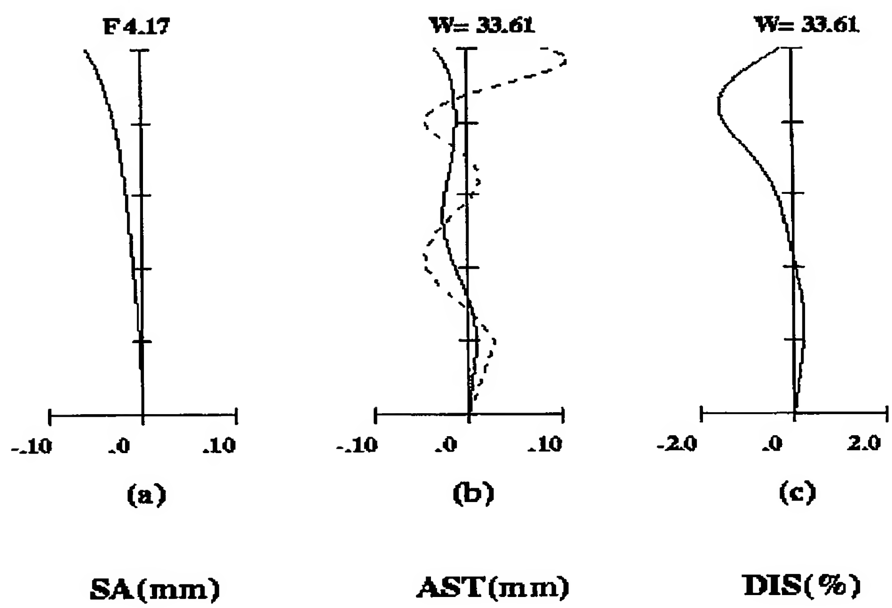
-.10
.0
.10
-.10
.0
.10
-2.0
.0
2.0
(a)
(b)
(c)
SA(mm)
AST(mm)
DIS(%)

[FIG.5]



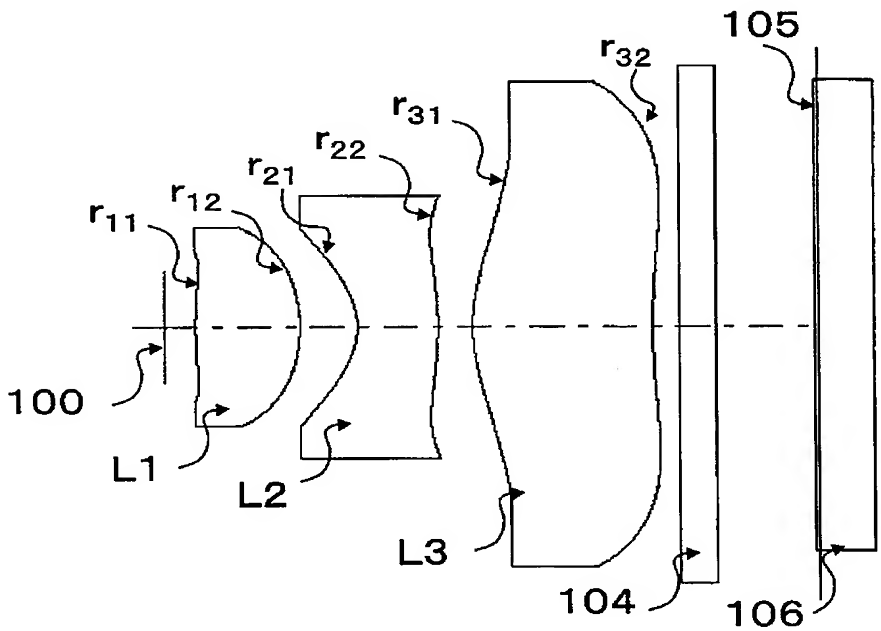
r11
r12
r21
r22
r31
r32
105
100
L1
L2
L3
104
106

[FIG.6]

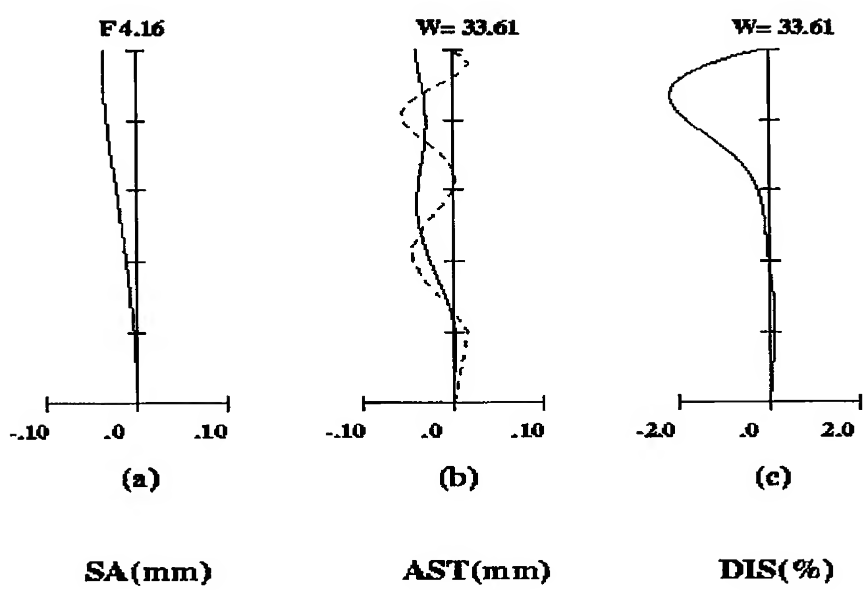


F4.17
W= 33.61
W= 33.61
-.10
.0
.10
-.10
.0
.10
-2.0
.0
2.0
(a)
(b)
(c)
SA(mm)
AST(mm)
DIS(%)

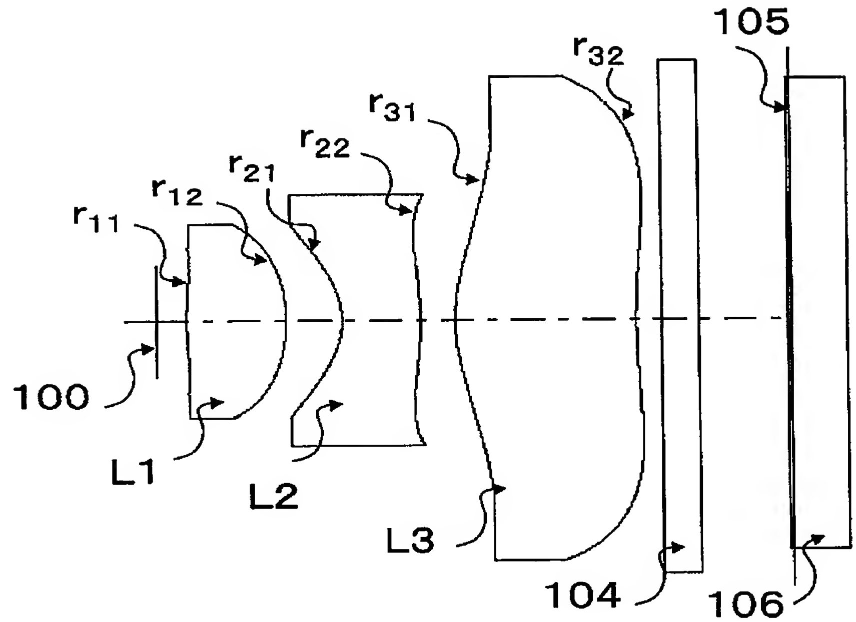
[FIG.7]


105
r32
r31
r22
r21
r12
r11
100
L1
L2
L3
104
106

[FIG.8]

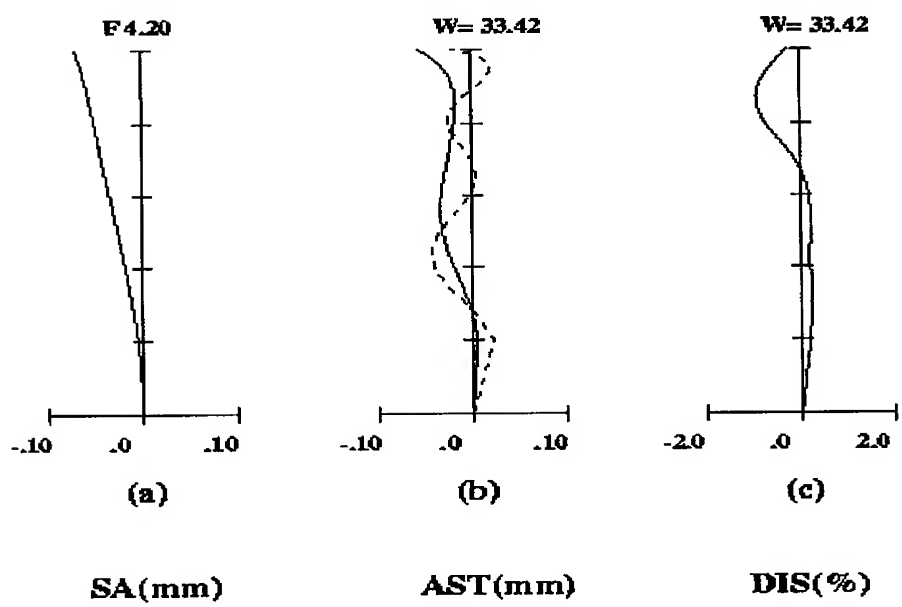

F4.16
W= 33.61
W= 33.61
-.10
.0
.10
-.10
.0
.10
-2.0
.0
2.0
(a)
(b)
(c)
SA(mm)
AST(mm)
DIS(%)

[FIG.9]



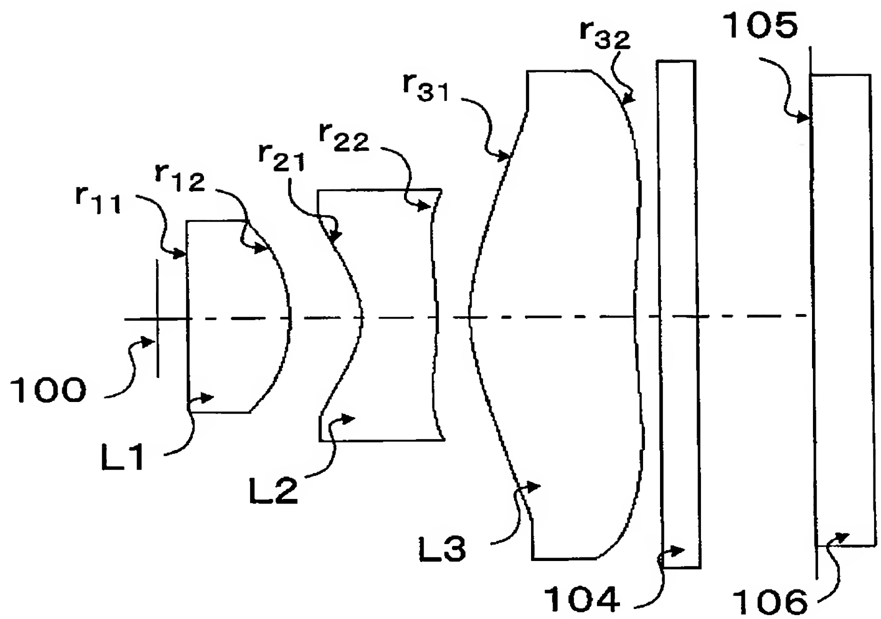
105
r32
r31
r22
r21
r12
r11
100
L1
L2
L3
104
106

[FIG.10]

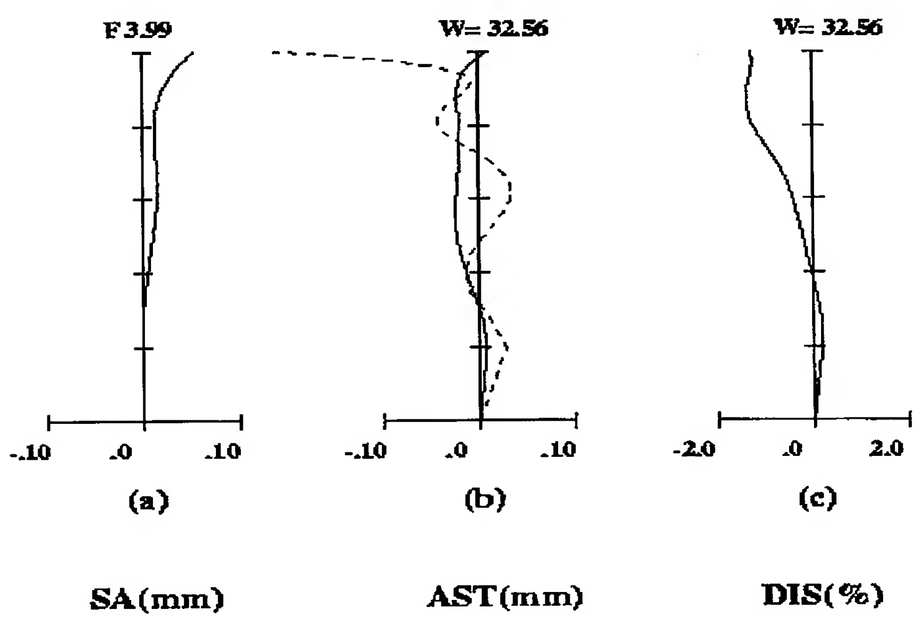


F4.20
W= 33.42
W= 33.42
-.10
.0
.10
-.10
.0
.10
-2.0
.0
2.0
(a)
(b)
(c)
SA(mm)
AST(mm)
DIS(%)

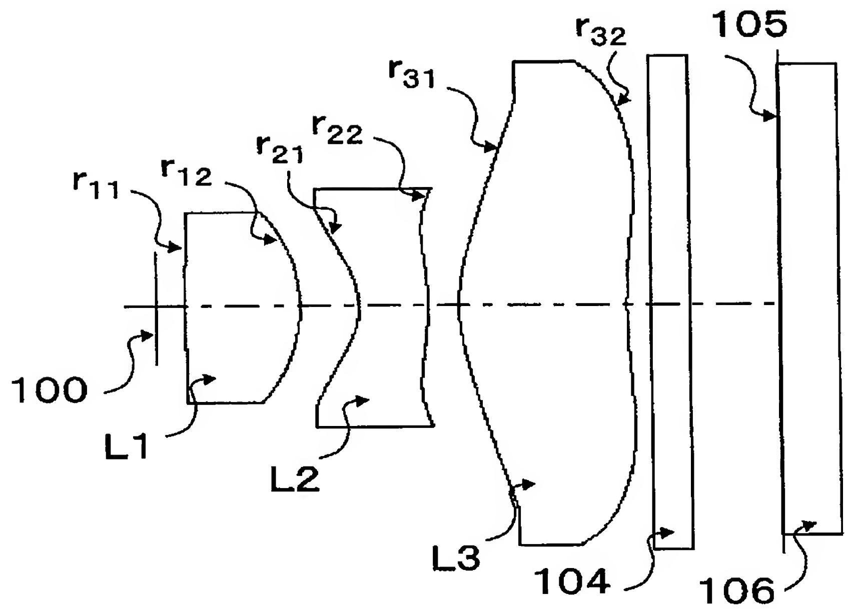
[FIG.11]


r32
105
r31
r22
r21
r12
r11
100
L1
L2
L3
104
106

[FIG.12]

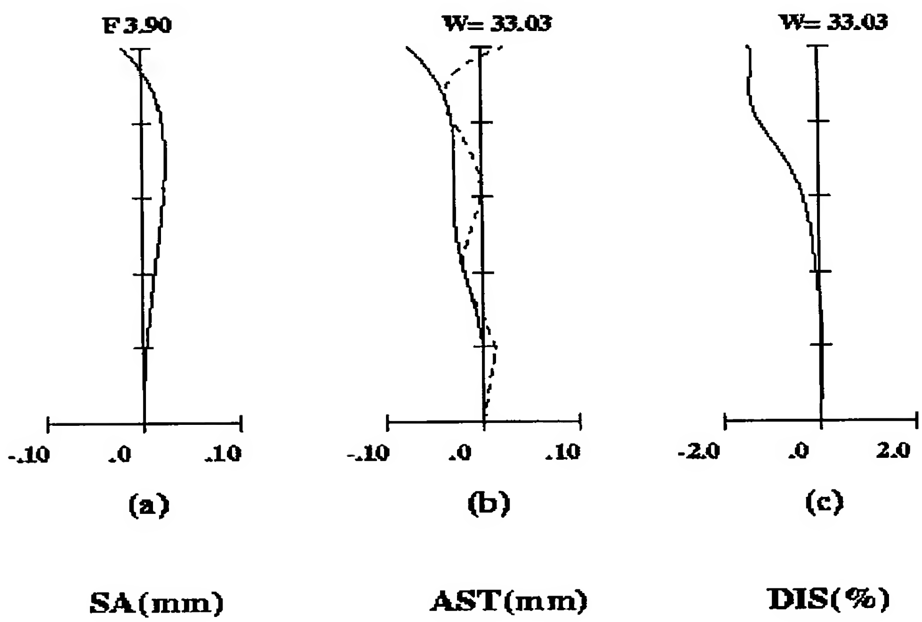

F 3.99
W= 32.56
W= 32.56
-.10
.0
.10
-.10
.0
.10
-2.0
.0
2.0
(a)
(b)
(c)
SA(mm)
AST(mm)
DIS(%)

[FIG.13]



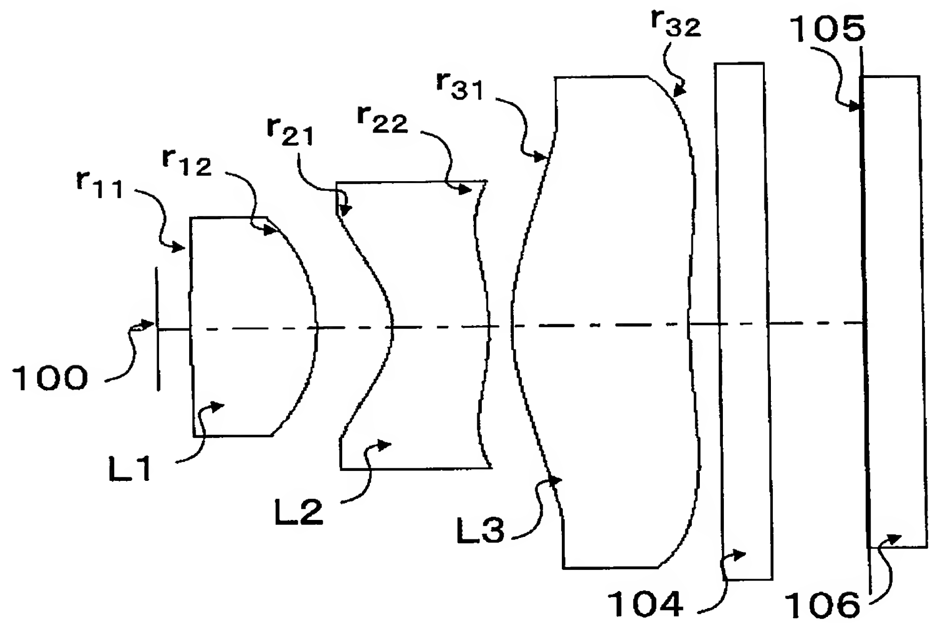
r11
r12
r21
r22
r31
r32
105
100
L1
L2
L3
104
106

[FIG.14]



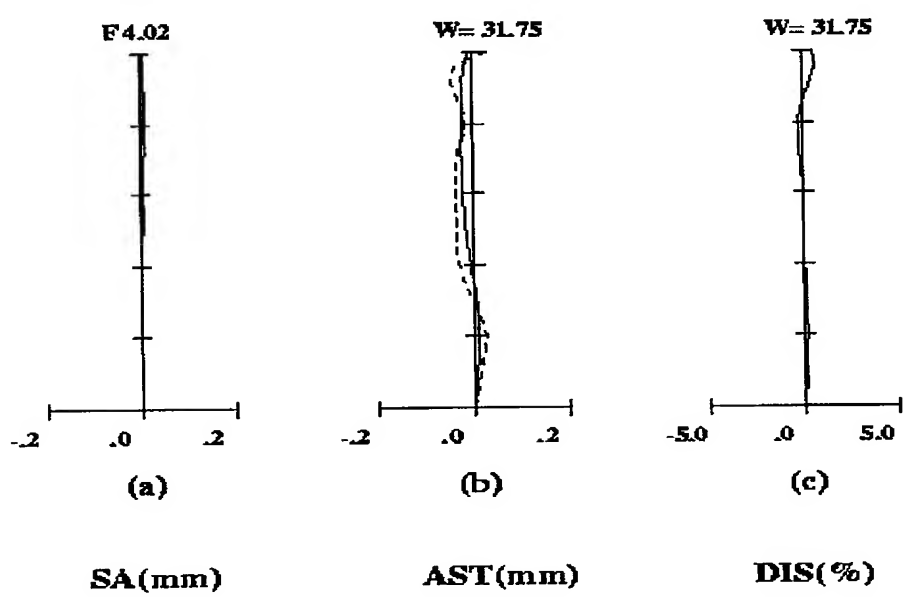
F3.90
W= 33.03
W= 33.03
-.10
.0
.10
-.10
.0
.10
-2.0
.0
2.0
(a)
(b)
(c)
SA(mm)
AST(mm)
DIS(%)

[FIG.15]



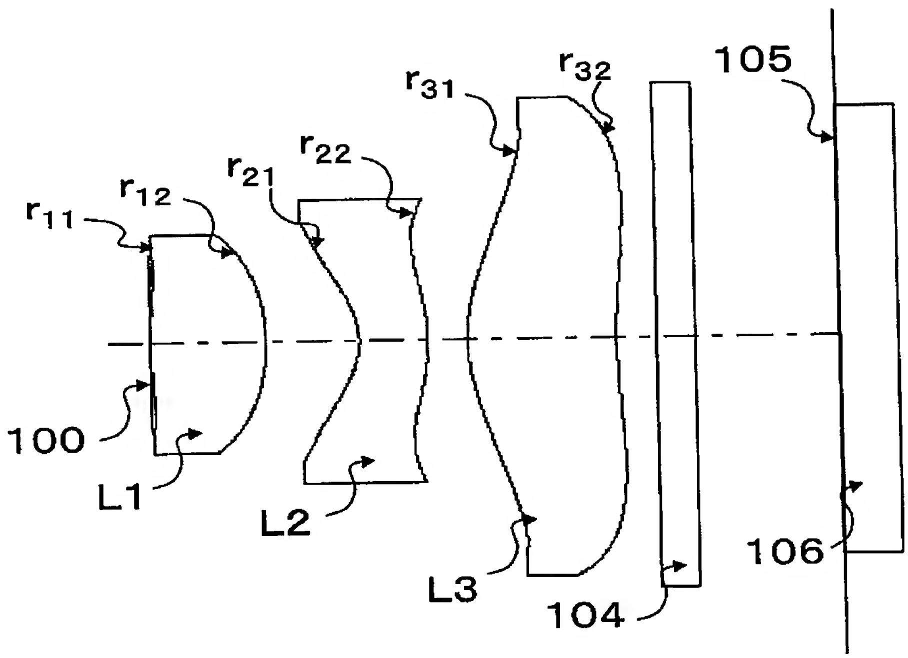
r32
105
r31
r21
r22
r12
r11
100
L1
L2
L3
104
106

[FIG.16]

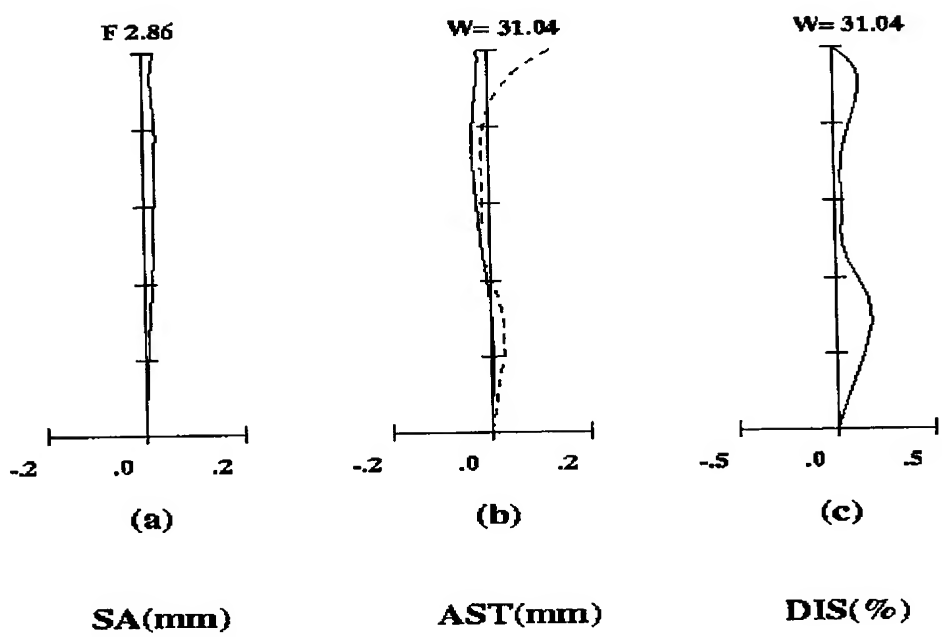


F4.02
W= 31.75
W= 31.75
-.2
.0
.2
-.2
.0
.2
-5.0
.0
5.0
(a)
(b)
(c)
SA(mm)
AST(mm)
DIS(%)

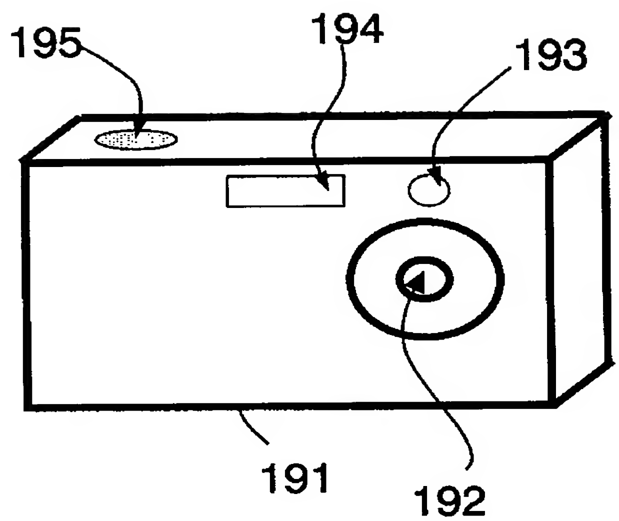
[FIG.17]


r11
r12
r21
r22
r31
r32
105
100
L1
L2
L3
104
106

[FIG.18]


F 2.86
W= 31.04
W= 31.04
-.2
.0
.2
-.2
.0
.2
-.5
.0
.5
(a)
(b)
(c)
SA(mm)
AST(mm)
DIS(%)

[FIG.19]



[Document Name] ABSTRACT

[Summary]

[Problem] The object is to obtain: an imaging lens having an entire lens system downsized, being excellent in portability, and being compatible with a large number of pixels by which a favorable image quality is provided; and an optical device provided with this imaging lens.

[Solution] In order from an object side, there are arranged: an aperture diaphragm; a first lens having a positive refractive power and being a bi-aspherical lens whose image side is convex; a second lens having a negative refractive power and being a bi-aspherical meniscus lens whose object side is concave; and a third lens having a positive refractive power and being a bi-aspherical meniscus lens whose object side is convex.

[Selected Figure] FIG. 1